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Sustainable strategies for controlling pigeonpea wilt complex with *Trichoderma asperellum* and fungicides

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Abstract
Pigeonpea (*Cajanus cajan* (L.) Millsp.) is the important legume crop in india. Wilt complex of pigeonpea is major constraint in pigeonpea production caused by *Fusarium udum, Rhizoctonia bataticola* and *Phytophthora drechsleri* f. sp. *cajani.* The experiment was carried out at research fields of Dr. PDKV, Akola in *Kharif* 2023-24 for the management of pigeonpea wilt complex by using *Trichoderma asperellum* and Metalaxyl 4%+ Mancozeb 64% WP (Ridomil gold MZ) with seven treatment combinations. Experiment was carried out in three fields with different cropping patterns *viz.*, pigeonpea sole, pigeonpea - soybean and pigeonpea - cotton intercropping. Per cent wilt incidence observed in pigeonpea sole cropping (42.66%) was higher in absolute control at 150 DAS than in intercropping with soybean (35.66%) and cotton (34%). Among seven treatment combinations lowest disease incidence was observed in T_6- seed treatment with *Trichoderma asperellum* and Carboxin 37.5% + Thiram 37.5% DS and three times foliar spray of Metalaxyl 4% + Mancozeb 64% WP in all three cropping patterns *viz.*, pigeonpea sole (19.66%), pigeonpea - soybean (16%) and pigeonpea - cotton (14.66%) with the highest per cent disease control 53.91, 55.13 and 56.88% respectively. Followed by T_4- seed treatment with *Trichoderma asperellum* and Carboxin 37.5% + Thiram 37.5% DS and soil application of *Trichoderma asperellum* at the time of sowing, 30 and 60 DAS which had also shown good results with per cent disease incidence 22, 18 and 16.33% respectively in pigeonpea sole, pigeonpea - soybean and pigeonpea - cotton with per cent reduction of disease over control 48.42, 49.52 and 51.97% respectively.

Keywords: Fungicide, incidence, metalaxyl, pigeonpea, per cent disease control, phytophthora blight, Trichoderma, wilt complex

Introduction
Pigeonpea [*Cajanus cajan* (L.) Millsp.] an often cross-pollinated, diploid perennial grain legume, is the fourth most important food legume in the world after dry bean, field pea and chickpea. It is the most versatile grain legume crop grown in the semi-arid tropical and subtropical regions. The most common vernacular names for pigeonpea are arhar, red gram and tur (India). It provides a high-quality diet for human consumption as a main source of protein, especially for vegetarian population of the Indian subcontinent. It is also used in stock feed rations. Being a perennial crop, it is used for soil conservation. Pigeonpea grown in rotation with cereals increases the yield of cereals by enhancing soil nitrogen and breaking the disease cycle of important cereal pathogens. Because of its tolerance to heat and drought, it is suitable for low-fertility soils.

Pigeonpea contributes 5 per cent of world legume production (Hillocks *et al.*, 2000) [14] and more than 70 per cent is being produced in India. Globally, pigeonpea is grown in an area of 63.57 lakh hectares with a production of 54.75 lakh tonnes and productivity of 861.25 kg/ha (FAO STAT, 2021) [8]. India ranks first in pigeonpea production globally with 43.4 lakh tonnes cultivated under 49.8 lakh hectares with productivity of 871 kg/hectare in 2021-22 (agricoop.nic.in).

Even though being a crop of great relevance, pigeonpea cultivation is subjected to high yield losses every year. Stabilizing yield in pigeonpea is a major concern as its production is very much affected by several biotic and abiotic factors (Varshney *et al.*, 2013) [23]. Of the many factors resulting in the economic loss, diseases appear to be the major biological constraints to production. Wilt disease complex in pigeonpea is a major production constraint in India.

(Hasan,1984; Siddiqui and Mahmood, 1996 and 1999) [12, 19, 20]. The pigeonpea wilt complex is primarily caused by *Fusarium udum*, which leads to vascular wilting and other fungal pathogens like *Rhizoctonia bataticola*, responsible for dry root rot and *Phytophthora drechsleri* f. sp. *cajani* which cause stem blight and wilt. These pathogens together weaken the plant, causing wilting, root decay and stem rot, leading to significant yield losses.

The wilt disease caused by *Fusarium udum* is the most important soil-borne disease and was first reported in Bihar state in India (Butler, 1906) [6]. Wilt is predominant in all major pigeonpea growing areas throughout the world and causes 30-100% yield loss, where resistance sources are not available (Biswas and Ghosh, 2016) [5]. Dry root rot caused by *Rhizoctonia bataticola* (*Macrophomina phaseolina*) is one of the most destructive diseases and cause severe yield loss in pigeonpea. Under favourable conditions, dry root rot and stem canker diseases will infect quickly and cause annual estimated yield loss up to 10-100 per cent (Smita *et al.*, 2015) [22]. The first suspected occurrence of phytophthora blight on pigeonpea in India was first reported in 1966 by Williams *et al.*, 1968 [24]. Recently, the recurrence of phytophthora blight was reported and has become a major threat to pigeonpea production and productivity in the Deccan Plateau of India irrespective of cropping system, soil types and cultivars (Pande *et al.*, 2011) [15]. The effect of Phytophthora blight on grain yield depends on the appearance of the disease during the crop growth period which largely depend on weather conditions and inoculum levels of the pathogen. The information on total losses caused by phytophthora blight is lacking, but it is axiomatic that the disease is of growing importance and can cause havoc in favorable conditions and susceptible cultivar.

Managing the wilt complex is challenging due to the persistent nature of these soil-borne fungi, but through an integrated approach of seed treatment, foliar spray and soil application of fungicides and bioagents is highly effective. Chemical control of pigeonpea wilt complex particularly through fungicide is effective both in eliminating the primary infection from seeds (Haware *et al.* 1978) [13] as well as reducing the secondary spread of pathogen in soil.

Fungicides have become more inevitable options in managing the plant diseases specifically in absence of resistant varieties. The fungicides are inhibiting infection of fungi and then development and reproduction and can be very effective way to prevent or minimizing the impact of plant diseases. Phenylamides (Acylanilides) group of chemicals, Metalaxyl was most widely used against the wilt complex of pigeonpea. Metalaxyl 35% SD has been used as a seed protectant to manage the *Phytophthora* spp. Ridomil MZ has an additional advantage that it possesses different modes of action and there is a lower chance of cross-resistance with Metalaxyl-resistant populations. Mancozeb in combination with Metalaxyl was found to be highly effective at reducing disease. However, the chemical method of controlling wilt complex is not economical and eco-friendly.

Though management of disease with chemicals is highly effective, the growing concern on pesticide toxicity has warned for searching alternatives. In this direction, biological control is considered as an eco-friendly and best alternative for managing the plant diseases and to overcome the problems of pesticide residue toxicity and development of pathogens resistance to chemical pesticides (Akhtar and Siddiqui, 2008) [1]. The combination of fungicides and bioagents is crucial in managing pigeonpea wilt complex because it provides both immediate and long-term protection. Fungicides offer quick, targeted control of pathogens like *Fusarium* spp. and *Phytophthora* spp. while bioagents like *Trichoderma* spp enhance soil health and provide sustainable, long-term suppression of these pathogens. This integrated approach reduces chemical use, delays resistance development in pathogens and promotes overall plant and soil health, making it a more effective and eco-friendly management strategy.

Considering the importance of pigeonpea in the current pulse crops scenario of our country and potential losses caused by pigeonpea wilt complex in all crop growing areas, the present investigation was carried out under different cropping patterns of Vidarbha.

Materials and Methods

The experiment was conducted at research fields of Dr. PDKV, Akola in randomized block design at three fields with different cropping patterns *viz.*, pigeonpea sole, pigeonpea - soybean and pigeonpea - cotton with seven treatments and three replications combinations *viz.*, T_1- seed treatment of *Trichoderma asperellum* 10g/kg and Carboxin 37.5% + Thiram 37.5% DS 3g/Kg, T_2- T_1 + soil application of *Trichoderma asperellum* @ 2kg/acre at the time of sowing, T_3 - T_1 + soil application of *Trichoderma asperellum* @ 2kg/acre at the time of sowing and 30 DAS, T_4 - T_1 + soil application of *Trichoderma asperellum* @ 2kg/acre at the time of sowing, 30 DAS and 60 DAS, T_5 - T_1 + Foliar spray of Metalaxyl 4% + Mancozeb 64% WP @ 2g/ litre of water at 15 DAS, T_6 - T_1 + Three times foliar spray of Metalaxyl 4% + Mancozeb 64% WP @ 2g/ litre of water at 15 days interval starting from 15 DAS, T_7 - Untreated control.

Fungicide and bio-agent treated seeds of pigeonpea cv. PKV Tara (TAT-9629) was sown on dated 14 July 2023. The crop was grown by applying all recommended packages of practices and irrigated as and when required. The number of wilted and healthy plants were counted and wilt incidence was calculated. The per cent disease incidence and per cent disease control was calculated by using following formula.

Per cent disease incidence (PDI): observations were recorded at 30, 60, 90, 120 and 150 days after sowing. Per cent disease incidence (PDI) was calculated by using the formula given below:

$$\text{Percent Disease Incidence (PDI)} = \frac{No.of\ plants\ infected}{No.of\ total\ plants\ observed} \times 100$$

Per cent disease control (PDC): The per cent disease control was calculated by using the formula given below

$$\text{Percent Disease Control (PDC)} = \frac{C - T}{T} \times 100$$

Results and Discussion

Different fungicides and bioagents were tested either by seed treatment, foliar spray and soil application or by combination as shown in material and methods. Experiment was planned in Randomized Block Design (RBD) with three

replications. Seeds were treated with different fungicides or bioagents as shown in material methods. After seed treatment seeds of susceptible cultivar (PKV Tara) were sown. Results of integrated disease management of pigeonpea wilt complex in different cropping patterns were recorded during *Kharif* 2023-24 by employing seven treatments in combination (Table 1, 2 & 3 and Fig.1).

All the treatments were significantly effective over control in all three cropping patterns. Results revealed that the per cent disease incidence was higher in pigeonpea sole cropping (42.66%) than in intercropping with soybean (35.66%), followed by intercropping with cotton (34%) in untreated control. The lowest disease incidence was observed in T_6 (T_1 + three times foliar spray of Metalaxyl 4% + Mancozeb 64% WP) in all three cropping patterns *viz*., pigeonpea sole (19.66%), pigeonpea - soybean (16%) and pigeonpea - cotton (14.66%) with the highest per cent disease control 53.91, 55.13 and 56.88% respectively. Followed by T_4 (T_1 + soil application of *Trichoderma asperellum* at the time of sowing, 30 DAS and 60 DAS) which had also shown good results with per cent disease incidence 22, 18 and 16.33% respectively in pigeonpea sole, pigeonpea - soybean and pigeonpea - cotton with per cent reduction of disease over control 48.42, 49.52 and 51.97% respectively. In T_3 (T_1 + soil application of *Trichoderma asperellum* at the time of sowing and 30 DAS), per cent disease incidence was 25.66, 23 and 20% in all three cropping patterns respectively with per cent reduction of disease over control was 39.84, 35.50 and 41.17 per cent, which was followed by T_5 (T_1 + foliar spray of Metalaxyl 4% + Mancozeb 64% WP at 15 DAS), per cent disease in pigeonpea sole(31%), pigeonpea - soybean (25.33%) and pigeonpea - cotton (24.66%) with per cent disease reduction over untreated control was 27.33, 28.96 and 27.47% respectively. Followed by T_2 (T_1 + soil application of *Trichoderma asperellum* at the time of sowing) with per cent disease incidence pigeonpea sole (32.33%), pigeonpea - soybean (26%) and pigeonpea - cotton (25.66%) which had per cent disease reduction over untreated control was 24.21, 27.08 and 24.52% respectively. The highest per cent disease incidence was observed in T_1 (seed treatment of *Trichoderma asperellum* @ 10g/kg + Carboxin 37.5% + Thiram 37.5 DS @ 3g/kg of seed) with pigeonpea sole (37.33%), pigeonpea - soybean (31.66%) and pigeonpea - cotton (29.66%). The lowest per cent disease control was found in T_1 with the pigeonpea sole (12.49%), pigeonpea - soybean (11.21%) and pigeonpea - cotton (12.76%).

Management of wilt complex pathogens as they are soil borne pathogens like *Fusarium udum*, *Rhizoctonia bataticola* and *Phytophthora drechsleri* f.sp. *cajani* by cultural methods is not effective since they are capable of producing prolong survival structures (Chlamydospore, sclerotia and oospore). Use of resistant cultivars is the best management strategy but availability and durability of resistant cultivars are also the major setback. Under such conditions, integrating bioagents and fungicides provides a promising alternative for effective disease management.

Table 1: Effect of *Trichoderma aspepellum* and Metalaxyl 4% + Mancozeb 64% WP on pigeonpea wilt complex in pigeonpea sole cropping

Tr. No.	Per cent Disease Incidence					Per cent disease control
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	
T_1	3 (9.88)	10.33 (18.72)	16 (23.55)	27.33 (31.51)	37.33 (37.65)	12.49
T_2	2.33 (8.46)	8 (16.34)	14 (21.94)	24 (29.31)	32.33 (34.64)	24.21
T_3	1.66 (7.15)	5.33 (13.34)	11.66 (19.89)	19.66 (26.31)	25.66 (30.41)	39.84
T_4	2 (7.94)	5.66 (13.68)	9.33 (17.75)	15.66 (23.30)	22 (27.95)	48.42
T_5	1.41 (6.19)	3.33 (10.40)	13 (21.09)	22.66 (28.41)	31 (33.81)	27.33
T_6	1.08 (5.57)	2.33 (8.46)	7.66 (16.06)	12.33 (20.51)	19.66 (26.31)	53.91
T_7	6.33 (14.51)	13.33 (21.39)	22.33 (28.18)	32.66 (34.84)	42.66 (40.77)	0
F' test	Sig.	Sig.	Sig.	Sig.	Sig.	
S. E.(m)±	1.5488	1.0569	0.7998	0.8633	0.9457	
C.D (P=0.05)	4.7723	3.2567	2.4645	2.6600	2.9139	

(*Values in parenthesis are arc sin.)

Table 2: Effect of *Trichoderma aspepellum* and Metalaxyl 4% + Mancozeb 64% WP on pigeonpea wilt complex in pigeonpea - soybean intercropping

Tr. No.	Per cent Disease Incidence					Per cent disease control
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	
T_1	3 (9.88)	9.66 (18.05)	15.33 (23.02)	25.33 (30.21)	31.66 (34.22)	11.21
T_2	2 (7.94)	6.66 (14.92)	12.66 (20.82)	21.66 (27.73)	26 (30.63)	27.08
T_3	1.41 (6.19)	5.33 (13.34)	11.66 (19.89)	17.66 (24.84)	23 (28.64)	35.50
T_4	2 (7.94)	5.66 (13.68)	9 (17.44)	12 (20.25)	18 (25.08)	49.52
T_5	1.66 (7.15)	3.33 (10.40)	11 (19.33)	19 (25.82)	25.33 (30.20)	28.96
T_6	1.33 (6.53)	2 (7.94)	5.66 (13.72)	11 (19.35)	16 (23.55)	55.13
T_7	5 (12.87)	11 (19.32)	17.66 (24.84)	27.66 (31.72)	35.66 (36.65)	0
F' test	Sig	Sig	Sig	Sig	Sig	
S. E.(m)±	1.20	1.03	0.64	0.60	0.88	
C.D (P=0.05)	3.69	3.16	1.98	1.84	2.71	

(*Values in parenthesis are arc sin.)

Table 3: Effect of *Trichoderma aspepellum* and Metalaxyl 4% + Mancozeb 64% WP on pigeonpea wilt complex in pigeonpea - cotton intercropping

Tr. No.	Per cent Disease Incidence					Per cent disease control
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	
T_1	3 (9.88)	9.33 (17.75)	14.66 (22.48)	23.66 (29.10)	29.66 (32.99)	12.76
T_2	2 (7.94)	6.33 (14.56)	11.66 (19.96)	21.66 (27.71)	25.66 (30.43)	24.52
T_3	1.66 (7.15)	5 (12.87)	11 (19.32)	17.66 (24.84)	20 (26.55)	41.17
T_4	2 (7.94)	5.33 (13.26)	8.66 (17.00)	11.66 (19.95)	16.33 (23.82)	51.97
T_5	1.75 (6.99)	3 (9.88)	10.66 (19.00)	20 (26.54)	24.66 (29.75)	27.47
T_6	1.08 (5.57)	2.08 (7.51)	6 (14.14)	10.33 (18.73)	14.66 (22.50)	56.88
T_7	4.33 (11.89)	10 (18.42)	16.66 (24.06)	26.66 (31.08)	34 (35.66)	0
F' test	N. sig	Sig	Sig	Sig	Sig	
S. E.(m)±	1.55	1.15	0.97	0.75	0.81	
C.D (P=0.05)	4.74	3.54	2.98	2.31	2.48	

(*Values in parenthesis are arc sin.)

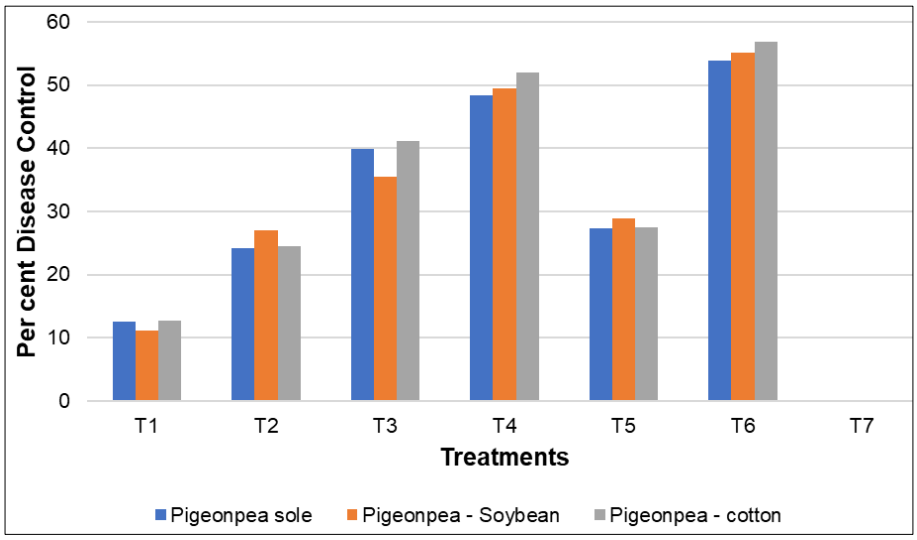

Fig 1: Per cent disease control in different cropping patterns of pigeonpea

Vitavax Power (Carboxin 37.5% + Thiram 37.5% DS) is a broad-spectrum, dual-action (systemic and contact) fungicide formulated as a dry seed dressing (DS) containing a combination of Carboxin and Thiram. Carboxin is a systemic fungicide that inhibits cell division in fungi, while Thiram is a contact fungicide that disrupts multiple cellular processes in fungi. By targeting these essential cellular functions, Vitavax Power effectively controls a wide range of pathogens, particularly seed and soilborne pathogens and acts as a plant growth stimulant. In our study seed treatment of Carboxin 37.5% + Thiram 37.5% DS in combination with *Trichoderma asperellum* @10 g/kg of seed, shows the good control over the diseases in initial days.

Ridomil Gold (Metalaxyl-M 4% + Mancozeb 64% WP) plays a critical role in managing the wilt complex in pigeonpea, a disease caused by *Fusarium udum* in association with other soilborne pathogens such as *Rhizoctonia bataticola* and *Phytophthora drechsleri* f. sp *cajani*. The systemic component, Metalaxyl-M, specifically inhibits the RNA synthesis of oomycetes, curbing their establishment and spread within the plant's vascular system. Meanwhile, Mancozeb, a contact fungicide, offers multi-site activity, creating a protective barrier on plant surfaces and preventing secondary infections. This dual action not only suppresses pathogen growth but also reduces soilborne inoculum levels, contributing to long-term disease management. Its use is particularly beneficial during early crop stages when plants are highly susceptible to infection. Chemical management is rarely effective in the presence of a high inoculum level and favorable meteorological conditions. As a result, a realistic and cost-effective option would be to cultivate resistant cultivars or to combine bioagent with a lower dose of fungicide. The combination of bioagents and lower doses of chemical fungicides has lately gained popularity in sustainable agriculture (Someya *et al*., 2007 and Andrabi *et al*., 2011). The present study, seed treatment with *Trichoderma asperellum* and Carboxin 37.5% + Thiram 37.5% DS followed by three times foliar spray of Metalaxyl 4% + Mancozeb 64% WP at interval of 15 days, effectively reduced the wilt incidence in the field trials.

The results of present investigation were similar with earlier reports made by previous researchrers. Bisht *et al.*, (1988) [4] and Sharma *et al.*, (2023) [17] found that foliar spray of Metalyxyl 4% + Mancozeb 64% WP was effective in management of *P. drechsleri* which causing stem blight and wilt in pigeonpea. Jadesha *et al*., 2019 conducted the trail on management of phytophthora blight in pigeonpea by combining the reduced dose of Mefenoxam + Mancozeb and the bioagent *Trichoderma asperellum*. The results revealed that Mefenoxam + Mancozeb (Ridomil Gold MZ 68% WG) and Metalaxyl (Apron 35% SD) were highly inhibitory to mycelial growth of *Phytophthora drechsleri* f.sp. *cajani*. Further seed treatment with Mefenoxam + Mancozeb and combination of Mefenoxam + Mancozeb and *Trichoderma asperellum* significantly reduced the phytophthora blight caused by under greenhouse and field conditions in three pigeonpea cultivars (ICP 87119, ICP 8863 and ICP 7119)

tested. Mamata and Gaviyappanavar (2023) evaluated different fungicide application methods for controlling phytophthora blight of pigeonpea, in which they found the seed treatment + soil drenching, soil drenching + foliar spray and soil drench application methods were found to be effective in controlling the Phytophthora blight. A combination of the seed treatment + soil drench and soil + foliar spray methods, using Metalaxyl- M + Mancozeb or Metiram + Dimethomorph fungicides on moderately resistant cultivars (ICPL 99010) has a synergistic effect on the ability to control the phytophthora blight at the seedling stage.

Singh and Dubey (2010) [21] founded seed treatment and soil application of *Trichoderma asperellum* was effective in controlling pigeonpea wilt complex pathogens *viz.*, *F. udum*, *R. bataticola* and *P. drechsleri* respectively. Because the *Trichoderma* spp. have the potential to control a wide range of phytopathogenic fungi as antagonists. The antagonism of Trichoderma involves several mechanisms, such as competition for nutrient antibiosis and production of fungal cell wall degrading enzymes. The mycoparasitic ability of Trichoderma species against plant pathogenic filamentous fungi enable them to exploit for biocontrol of many soil borne pathogens (Benitez *et al.*, 2004) [3].

Our research presents encouraging results on the management of pigeonpea wilt complex; however, additional work is required to confirm and expand these findings. Extensive multi-location trials under varying environmental and soil conditions are essential to evaluate the broader applicability and effectiveness of the proposed strategies. Furthermore, long-term studies are needed to monitor pathogen population dynamics, potential resistance development to Ridomil Gold MZ and its compatibility with biological control agents. Investigating the synergistic effects of integrated disease management (IDM) approaches and fine-tuning application techniques can enhance the precision and sustainability of these practices. Such future work will strengthen the scientific basis for adopting these methods at a larger scale, ensuring consistent performance and economic viability for farmers.

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